Marine Physical Laboratory

Energy Exchange Between Surface and Internal Waves; Soliton-like Wave-Packets in the Wake of a Ship; Excitation and Generation of Short Capillary Waves by Longer Waves

Kenneth M. Watson

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[1]We have shown that an energy transfer of the order of $10^4\ \omega/m^2$ can occur between surface and internal waves. The transfer is predominantely from the internal to the surface waves, but it can go either way, depending on the Vaisala frequency profile and the surface wave spectrum. We are putting together a database of wind and Vaisala profiles for the North Pacific in order to evaluate the implications of this transfer.

[2]A study of the possible soliton-like waves in the Kelvin wave of a surface vessel was investigated. The objective of the experiment was to tow a number of ship models and other "shapes" to investigate the mechanism for generating persistent nonlinear features. Hydrodynamic calculations were consistent with the observations.

[3]Observational evidence suggests that at low wind speeds(≤ 6 m/s) direct generation of wind cannot account for the capillary wave spectrum (wavelengths ≤ 2 cm). A theoretical treatment for this has been developed (in collaboration with John McBride) that uses a novel form of canonical transformation theory. This theory avoids the conventional problem with resonant oscillation. Application to study steepening of short gravity were investigated.

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Project 1: Energy Exchange Between Surface and Internal Waves
Project 2: Soliton-like Wave-Packets in the Wake of a Ship
Project 3: Excitation and Generation of Short Capillary Waves by Longer Waves

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Abstract

The energy transfer between surface and internal waves was investigated using historical wind and Vaisala frequency data for the North Pacific. Significant energy transfer from internal to surface waves was found for summer and fall conditions. In addition to the use of resonant triad theory, this transfer may be obtained using ray path theory. Implications for this was investigated. (Project 1)

A study of the possible soliton-like waves in the Kelvin wave of a surface vessel was investigated. The objective of the experiment was to tow a number of ship models and other "shapes" to investigate the mechanism for generating persistent nonlinear features. Hydrodynamic calculations were consistent with the observations. (Project 2)

Observational evidence suggests that at low wind speeds (≤ 6 m/s) direct generation of wind cannot account for the capillary wave spectrum (wavelengths ≤ 2 cm). A theoretical treatment for this has been developed (in collaboration with John McBride) that uses a novel form of canonical transformation theory. This theory avoids the conventional problem with resonant oscillation. Application to study steepening of short gravity were investigated. (Project 3)

Objectives

Numerical calculations appear to show reasonable agreement with observed spectra. The objective has been to investigate the mechanisms of coupling between IW's and SW's and to calculate the expected energy transfer using archived ocean data. This theory avoids the conventional problem with resonant oscillation. Application to study steepening of short gravity were investigated. (Project 1).

The objective of the experiment was to tow a number of ship models and other "shapes" to investigate the mechanism for generating persistent nonlinear features. A detailed analysis of the data was obtained. The objective was to determine the effect of hull shape, speed, and transients in generating persistent wake features. Studies were made to determine the theoretical analysis of boundary conditions that lead to Bryant-like oblique nonlinear wave packets. (Project 2)

The objective was to investigate the combined role of wind and nonlinear hydrodynamic interactions in determining the spectrum of capillary waves.(Project 3)

Results

Project 1

A theoretical formulation of the energy exchange between surface waves (SW) and internal waves (IW) was published[1] and described further in[2]. An extensive database for North Pacific wind and Vaisala frequency profiles has been put together and used to evaluate IW-SW energy exchange. A significant transfer from the IW field to the SW field was found, as anticipated[1].

To better illustrate the physical processes of SW-IW energy exchange, a reformulation in terms of surface ray path has been developed. For weak IW surface currents, the earlier results are obtained. For strong IW surface currents new mechanisms are involved.

This work is now complete and will be prepared for publication.

Project 2

No work was done during the project period on Project 2. Instead, after discussion with the Office of Naval Research Project Officer, an investigation was undertaken of the generation of capillary waves by longer waves (Project 3).

Project 3

Recent work by Jaehne and Riesner[3] has shown that capillary wave generation by longer waves is important in maintaining the capillary spectrum. A novel technique was developed in collaboration with John McBride to calculate this and related capillary wave phenomena[4].

The capillary wave spectra calculated[4] agree rather well with Jaehne's observation. Calculations of shifted capillary wave phase velocities also seem to agree with Jaehne's observations.

The technique used[4] makes use of the Lie transform theory of canonical transformations to "remove" wave-wave interaction, except for "triad resonant" interactions. On inverting the Lie transform wave coherence effects, such as modulation of short waves by long waves is exhibited[5].

ONR Publications

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Watson, K.M., 1991: Coupling of Surface and Internal Waves. University of Hawaii, January. (Invited Presentation)

Watson, K.M., 1991: Scattering Theory. In **Encyclopedia of Physics**, Edited by R. Lerner and G Trigg, VCH Publishers, Inc., New York.

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